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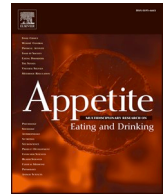


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Portion size influences intake in Samburu Kenyan people not exposed to the Western obesogenic environment

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ABSTRACT

For people in the modernized food environment, external factors like food variety, palatability, and ubiquitous learned cues for food availability can overcome internal, homeostatic signals to promote excess intake. Portion size is one such external cue; people typically consume more when served more, often without awareness. Though susceptibility to external cues may be attributed to the modernized, cue-saturated environment, there is little research on people living outside that context, or with distinctly different food norms. We studied a sample of Samburu people in rural Kenya who maintain a traditional, semi-nomadic pastoralist lifestyle, eat a very limited diet, and face chronic food insecurity. Participants (12 male, 12 female, aged 20–74, mean BMI = 18.4) attended the study on two days and were provided in counterbalanced order an individual serving bowl containing 1.4 or 2.3 kg of a familiar bean and maize stew. Amount consumed was recorded along with post-meal questions in their dialect about their awareness of intake amount. Data were omitted from two participants who consumed the entire portion in a session. Even though the ‘smaller’ serving was a very large meal, participants consumed 40% more when given the larger serving, despite being unable to reliably identify which day they consumed more food. This result in the Samburu demonstrates the portion size effect is not a by-product of the modern food environment and may represent a more fundamental feature of human dietary psychology.

1. Introduction

The idea that external cues can promote overeating was established by the influential experiments of Schachter (1968), and has since developed into a comprehensive framework for how food-associated cues trigger hedonic and incentive responses that can override internal control processes (Berthoud, 2011; Lutter & Nestler, 2009) and can induce apparently sated individuals to eat (Cornell, Rodin, & Weingarten, 1989; Jansen et al., 2003; Johnson, 2013; Petrovich, Setlow, Holland, & Gallagher, 2002; Weingarten, 1983). For modern humans with constant access to palatable, energy dense food, external incentive stimuli can drive intake far beyond that needed to maintain immediate energy balance.

The *portion size effect* is one notable example of such susceptibility to external influence. The tendency to eat more when served a larger portion, often without awareness, has been widely demonstrated with many types of foods, in both laboratory and naturalistic settings (English, Lasschuijt, & Keller, 2015; Herman, Polivy, Pliner, &

Vartanian, 2015; Ledikwe, Ello-Martin, & Rolls, 2005; Zlatevska, Dubelaar, & Holden, 2014). This effect can also increase total intake cumulatively over periods of several days (Rolls, Roe, & Meengs, 2007), implicating it in weight gain. People often report similar subjective satiety despite eating more due to portion manipulation (Kral, Roe, & Rolls, 2004; Rolls, Morris, & Roe, 2002), calling into question the relative role of internal energy-related signals in meal termination for modern consumers.

Despite the extensive experimental work on how external influences like portion size promote excess intake, there is very little work investigating whether these factors act similarly for people living outside the modernized Western environment who are not affected by the industrialized food systems which provide abundant, inexpensive, energy dense processed foods. It would be informative to determine if this is the case.

There is reason to believe the predominance of external factors over internal, homeostatic signals of energy status is promoted by immersion in the modern environment, and a robust portion size effect could be

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one example of this broader process. The influence of external food cues in general and the portion size effect in particular have been attributed in part to socialization and explicit instruction (e.g., customary meal times, training children to clean their plates, norms for situational appropriateness) which habitually focus attention on external cues (Birch, McPhee, Shoba, Steinberg, & Krehbiel, 1987; Elliott, 2014; Herman et al., 2015; Ramsay et al., 2010). The ability of such cues to eclipse physiological signals and drive persistent overconsumption is often viewed as an aberrant state of adaptation to the modern obesogenic environment, which has been called “toxic” for how it dysregulates physiological and behavioral responses to food (Horgen & Brownell, 2002). Consistent with this view, it is often suggested that chronic exposure to extremely palatable, highly refined, processed foods can induce neural adaptations that increase the impact of external food-related cues on food intake - analogous to incentive sensitization in drug addiction (Berridge, Ho, Richard, & DiFeliceantonio, 2010; Stice, Figlewicz, Gosnell, Levine, & Pratt, 2013). Experience with the extreme variety of modern processed foods may also impair normal control processes (Davidson, Tracy, Schier, & Swithers, 2014) which would increase the influence of external cues. Notably, these models all share the same underlying assumption: that food intake would be more responsive to energy status (internal physiology) were it not for the disruptive influences of modernity.

However, such speculative hypotheses about effects of the modern food environment are difficult to scrutinize by only studying people who are immersed in it. Indeed, it is also possible that people not immersed in the obesogenic Western environment would be more, not less, responsive to external influences over intake like the portion size effect. In circumstances where food availability is chronically sporadic, sensitivity to cues for food availability and increased meal size during brief periods of abundance could be beneficial for maximally exploiting occasional eating opportunities. Rather than being a maladaptive adaptation to aberrant environmental conditions, the power of external cues to eclipse internal satiation signals could be a fundamental feature of a behavioral system that evolved to cope with food scarcity. In the environments in which humans and many other species evolved and in which many present-day humans still live, externalization and not reliance on internal, homeostatic signals could be the norm.

For these reasons, researching the behavior of present-day humans living outside the modern food environment would be instructive. In the current experiment we investigated the portion size effect because it is one of the most robust and widely replicated examples of an external influence on meal size (e.g., see reviews by Ello-Martin, Ledwidge, & Rolls, 2005; English, Lasschuijt, & Keller, 2015; Herman et al., 2015; Zlatevska et al., 2014). Limited cross-cultural comparisons that exist do suggest portion sizing correlates with variation in consumption habits, but those comparisons focus on Western urbanites (e.g., Paris vs Philadelphia (Rozin, Kabnick, Pete, Fischler, & Shields, 2003)). We are aware of only one study in a country not highly ranked on indicators of economic development. That study replicated the portion size effect in children in Kunming, China (Smith, Conroy, Wen, Rui, & Humphries, 2013) but little information on the sociocultural milieu was included to allow inferences about Western diet exposure.

We experimentally investigated the portion size effect as an assay of external vs internal responsiveness in meal size in the Samburu, semi-nomadic pastoralists who live in a remote, semi-arid region of North-Central Kenya. They live far outside the modern, industrialized, obesogenic environment, have retained much of their traditional herding lifestyle, and eat a simple diet comprised of their longstanding staples of milk, meat, and blood, now supplemented with a few purchased commodities—especially tea, sugar, maize, beans, and vegetable oil. A comprehensive account of Samburu foodways has been published by Holtzman (2009). Samburu are very lean and tolerate long periods of undernutrition and occasional severe famine. But, when food is available they value eating to their maximal capacity, a behavior that is strongly socially validated. Their narratives about large meals are often

phrased in competitive terms, such as refusing to be “defeated” by food. This behavior signifies vitality and is a source of pride and social admiration (Holtzman, 2009). When enough is available there is no expectation a person should limit their consumption for “appropriateness.” This is borne out by the very large meals and by the rapid return of appetite after eating we have previously documented in the Samburu (Brunstrom, Rogers, Myers, & Holtzman, 2015).

We studied Samburu participants using an experimental design that parallels studies of the portion size effect in typical Western populations (see reviews by English et al., 2015; Herman et al., 2015; Ledikwe et al., 2005; Zlatevska et al., 2014). Each participant was served a meal of the same familiar food on two occasions, but differing in portion size in counterbalanced order. The “smaller” meal was still larger than what an average participant would eat in one sitting, and the “larger” meal was 65% more. The presence or lack of a portion size effect would be informative given that their food environment and norms differ so strikingly from modern Westerners. If, without chronic disruptive influences of the modern environment intake is truly dictated mainly by internal physiological cues, then for Samburu people who are motivated to eat to maximal capacity, portion size should be irrelevant (as long as it exceeds that capacity). Since there have been conflicting observations in typical Western samples of whether people are aware when they eat more in response to portion size (e.g., Keenan, Childs, Rogers, Hetherington, & Brunstrom, 2018; Vartanian, Reily, Spanos, Herman, & Polivy, 2017), we also sought to determine if Samburu participants, who we know to value eating especially large meals, would be aware of any influence of portion size on their intake. Thus, after the second session participants were asked to report which day they believe they ate more. While this is not necessarily a proxy for subjective satiety ratings,¹ it would be of interest to know if any effect of portion size was operating within explicit awareness for people intentionally seeking to eat to capacity.

2. Methods

Participants, $n = 12$ females, 12 males, aged 20–74, with BMI (mean \pm SD) of females = 18.3 ± 2.06 , males = 18.5 ± 2.94 , were recruited in the Samburu district of Kenya. That sample size was decided prior to the experiment based on the practical limitations of data collection that could be accomplished in limited time at a remote field site. Using the average effect size 0.45 reported in a recent large meta-analysis of portion size studies (Zlatevska et al., 2014), the sample provided a 70% power to detect an effect. Procedures were approved by Western Michigan University Institutional Review Board and conducted in the Samburu dialect by local research assistants, supervised by one of the authors (J.D.H.) who is fluent in Kiswahili and proficient in Samburu. Informed consent was obtained from all participants.

Participants were served test meals of different portion sizes on consecutive days in counterbalanced order. The test food was *githeri*, a stew of maize and beans (~ 1.26 kcal/g) that is familiar and acceptable to the Samburu. It was prepared in a large batch daily with equal parts maize and beans, water sufficient for cooking, and a small amount of onion, salt, and vegetable oil.

Each participant's meal was provided in an individual serving bowl with ladle. The participant sat alone for the meal and ladled food from

¹ Though it is common to collect subjective satiety ratings for participants in such studies in typical Western samples, we have observed that Samburu people do not readily speak of satiety as a graded experience. This may reflect their powerful social norms for eating very large meals whenever possible. They typically describe themselves as being able and ready to eat more, or not. Thus, measures akin to numerical ratings of satiety are not feasible or culturally appropriate. We have previously found (Brunstrom et al., 2015) that Samburu are very capable of giving meaningful self-reports of *prospective* consumption when hungry, but those measures would not be useful for post-meal measurements in this experiment.

their serving bowl into a smaller soup bowl and ate with a spoon. On separate test days, in counterbalanced order, the serving bowl contained either a larger serving (~2.3 kg) or a smaller serving (~1.4 kg). These amounts were determined by our prior studies in Samburu, intending to minimize exclusion of participants for consuming the entire serving. The “smaller” serving size was somewhat larger than the typical intake we observed in a preliminary study, and the “larger” serving size was approximately 65% larger than the smaller serving.

Each participant attended on two consecutive days between 12:00 and 15:30, having refrained from eating for > 3 h. A random half of participants of each gender received the smaller portion size on the first day and the other half received the larger portion first. Participants were instructed to eat as little or as much as they wanted, and sat individually to eat. If a woman had a child with her during the test meal then they were themselves given the indicated portion and also a separate bowl of food for the child to eat so that the participant's intake could be accurately accounted. Intake was determined by weighing the meal (out of participants' sight) before serving and after completion. In a brief exit interview following the second session they were asked to name which session they believed they had eaten more.

2.1. Analysis plan

To determine if portion size influenced consumption, absolute intakes of the Smaller and Larger test meals were compared in a 2 (Portion Size) X 2 (Gender) X 2 (Order of Presentation) ANOVA with portion size as a repeated measures factor. Relative contribution of each of those factors to variation in intake was assessed by calculating partial eta-squared (η_p^2) for each from the ANOVA results. Then, planned contrasts were conducted for males and females separately, comparing intakes of the Smaller and Larger servings with paired *t*-tests. For descriptive statistics on the frequency and magnitude of the portion size effect, for each individual, a difference score was calculated to reflect the change in intake from the Smaller to the Larger condition. Prior to any analysis, data were excluded from one male and one female who consumed the entire serving on one of the test days, resulting in *n* = 11 females and 11 males. That exclusion is standard practice in portion size studies, since including those individuals biases the analysis towards a false positive effect if some participants' intakes were artificially limited by the serving size. In other words, in every test meal included in the analysis, more food remained available should the participant be inclined to keep eating.

3. Results

The participants consumed significantly more food when given the larger serving (Fig. 1). Portion size significantly affected intake, $F(1,18) = 15.69, p < .01, \eta_p^2 = 0.47$, but there was no effect of gender, $F(1, 18) = 0.43, p > .250, \eta_p^2 = 0.023$, nor did order of presentation have any effect independent of serving size, $F(1, 18) = 0.39, p > .250, \eta_p^2 = 0.021$. No interactions were statistically significant. Planned comparisons across serving size within each sex confirm the effect in both males (Mean \pm S.E.M intakes of Small and Large conditions respectively, 856.9 ± 66.4 g and 1129.6 ± 122.9 g, $t(10) = 2.29, p = .045, d = 0.75$) and females (756.1 ± 67.5 g and 1069.7 ± 103.1 g, $t(10) = 4.39, p = .002, d = 1.45$). The effect was robust, as 18 of the 22 participants consumed more in the larger portion session. The 65% increase in actual portion size caused a mean 40% increase in intake overall, 95% CI [19.5–61.1%]. The average increase of 293.3 g, 95% CI [151.3–435.2 g], corresponds to an increase in energy intake of approximately 370 kcal.

When asked which day they had consumed more, participants' answers suggested they were unaware of the rather large difference. Ten participants answered correctly and 12 answered incorrectly, and the answers were not predicted by which meal was actually larger

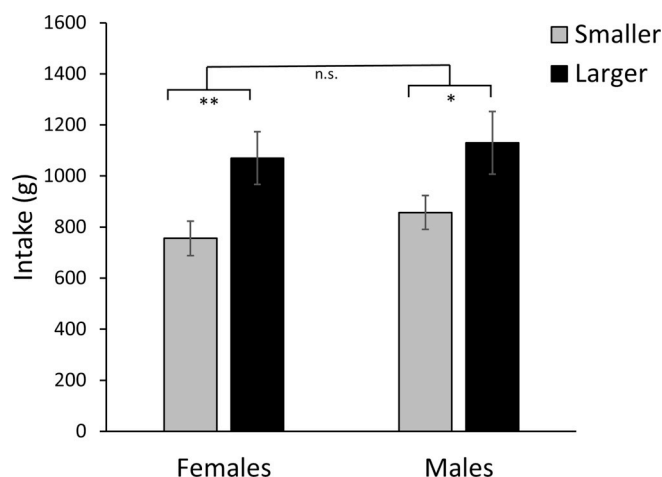


Fig. 1. Average ad libitum intake (mean \pm SEM) of Samburu women and men when provided 1.4 kg (Smaller) or 2.3 kg (Larger) test meals on two separate days in counterbalanced order. Data from one male and one female who consumed the entire serving in the Smaller condition are excluded, resulting *n* = 11 females and 11 males. The difference between Smaller and Larger conditions is statistically significant in females (***p* < .01) and males (**p* < .05), and overall intakes did not differ between females and males ($\chi^2 = 0.27, p > .250$).

Participants who ate very different amounts on the two days were not more likely to answer correctly (point-biserial correlation between correct/incorrect identification on this question versus the difference in intake between Large and Small meal and, $r = -0.038, p > .250$). It is unlikely that participants did not understand this question, as Samburu have provided us with meaningful patterns of self-report data about appetite sensations using more complex prospective questions (Brunstrom et al., 2015). Thus, the influence that portion size exerted on intake did not appear to depend on explicit awareness.

4. Discussion

In the context of Western overeating, the powerful effect of external cues on intake is often attributed at least partly to a chronic, dietary-induced desensitization of internal signaling of energy balance (e.g., Berthoud, 2011; Lutter & Nestler, 2009; Davidson et al., 2014). Portion size can be viewed as one such influence, as the presence of an especially large portion can lead people to consume more than they intend and, importantly, more than is necessary to maintain energy balance. Observing a portion size effect in Samburu participants changes the interpretation of this influence in two ways. First, because our volunteers had not been immersed in a Westernized environment yet the effect was quite large, it demonstrates that susceptibility to the portion size effect is not an outcome of chronic exposure to the modern food environment. Second, the Samburu participants consumed very large meals, yet, despite the desirability of eating to maximal capacity, their greater intake in the larger condition shows that they could have eaten more than they actually did in the smaller condition. Therefore, the portion-size effect appears to occur even when participants “intentionally overeat” (eat to capacity), which is inconsistent with an interpretation based on a so-called failure of internal controls.

The portion size effect observed in this study is especially noteworthy considering the absolute size of the meals our participants consumed. In our study, even the nominally-smaller portion was larger than any portion included in the most recent meta-analysis of over 100 portion-size effect studies (Zlatevska et al., 2014), and is a very large amount of food by Western standards. To illustrate this relative magnitude, we provide a figure that includes our current results

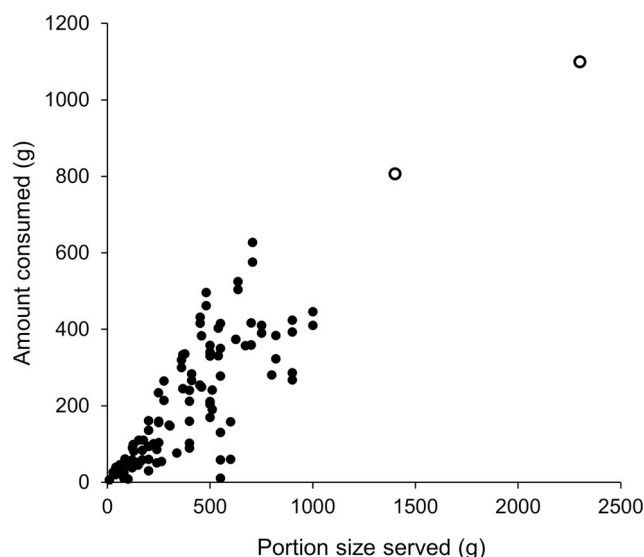


Fig. 2. Closed circles (93 observations) show the correspondence between the amounts of food served (g) and mean amount consumed (g) in published studies of the portion size effect (data taken from Zlatevska et al., 2014). Open circles show the same correspondence for the smaller and larger condition in Samburu participants in the present experiment.

superimposed on data derived from that meta-analysis.² (See Fig. 2). Of course, we cannot infer anything from our data about precisely how a sample of typical American or European participants would respond to these portions of the specific food we used. However, a conclusion from the Zlatevska et al., 2014 meta-analysis is that the effect of portion size on intake diminishes as absolute portions increase. They report that in experiments comparing across three or more portion sizes, the effect of increasing the portion is weaker for the larger portions than for the smaller portions. In the overall meta-analysis the relationship between portion size and intake stimulation is an inverse power function that flattens across the large portions (Zlatevska et al., 2014). Thus our Samburu participants demonstrated a significant stimulation by portion size that would not be predicted for Western consumers given that absolute amount of food. This underscores the significance of the effect as it occurred in a situation where participants are motivated to eat as much as possible, yet that upper limit on what's possible was clearly influenced by an external cue from the situation.

However, interpreting the magnitude of the effect relative to what has been reported in the many conventional portion size studies does raise one interpretive limitation of this study. Conventional portion size experiments with typical Western participants tend to base the experimental portions on some reference portion that is either explicitly or implicitly chosen for being customary and situationally appropriate for the participants. Our portions in this experiment were based on pilot observations of Samburu people serving themselves this food. Yet it is difficult to say that these represent “customary” portions, as Samburu cope with chronic food scarcity and do not eat routine meals when food is not available. We also have limited data characterizing the variability of food insecurity and other measures like daily habits across individual participants, and our sample size is too small to explore these as moderating variables. As a group, our Samburu participants clearly

² Data obtained from Table 1 of Zlatevska et al., 2014. In this table some studies compared effects of presenting several different portions (e.g., small vs medium and medium vs large). In these cases all data have been included. One study (Wansink, Painter, & North, 2005) was excluded because the amount served was not fixed and two studies were excluded because measures were taken over several days (Raynor & Wing, 2007; Rolls, Roe, & Meengs 2006). Other data were also removed where grams of food (served or eaten) were not reported.

differ dramatically from most Western participants in portion size experiments in terms of the very limited variety of foods they have access to, and in overall food availability as reflected by their low average BMIs. Given that this experiment establishes the existence of a fairly robust effect, additional research could be useful for exploring individual differences, in parallel with studies of Western populations.

Although our data do not directly compare Samburu people to Westerners, the very existence of a powerful portion size effect in this population urges reconsideration of some views on the portion size effect specifically and externalized control of appetite more generally. Instead of attributing the portion size effect as the result of socialization or neurobehavioral adaptations to chronic exposure to the modern food environment, our findings suggest that the prepotency of external controls of individual meals is the ordinary outcome of normal development in humans, representing a fundamental feature of human dietary psychology. This is consistent with the notion that forebrain mechanisms of reward anticipation which enable individuals to exploit environmental information about eating opportunities would be of considerable adaptive significance in ancestral environments characterized by intermittent food availability. Unlike the conventional model whereby tight homeostatic regulation of energy intake “fails” as the result of bombardment by external cues in an obesogenic environment, we argue that short-term balancing of appetite with energy status is actually inherently loose (Rogers & Brunstrom, 2016), with uniformly weaker input from physiological energy signals allowing the environment wide latitude to control meal size and patterning.

The ability of external food cues to elicit autonomic preparatory responses that stimulate appetite, known as “cue reactivity,” (Nederkoorn & Jansen, 2002) is well documented but not usually invoked in relation to portion size effects, despite evidence that individual differences in cue reactivity correlate with habitual portion size self-selection (Tetley, Brunstrom, & Griffiths, 2009). Large portions – especially the large amount that continually remains as the meal progresses – could conceivably influence intake by providing more potent triggers for these responses, and providing more continual cue-induced stimulation of appetite during the meal. This account would explain why the effect was large in Samburu people, and possibly larger than for Westerners. That is, although Westerners are exposed to ubiquitous food cues, most encounters are *not* actually followed by eating, and when they are, conscious restraint often makes meals smaller than desired. Thus, much of the time food cues are actually fairly weak predictors of impending caloric loads (except in binge eating disorders, wherein specific predictive stimuli can trigger binges (Jansen, 1998)). However, for Samburu coping with frequent food scarcity, the visual, gustatory, and olfactory stimuli of cooked food in particular would be a faithful predictor of impending consumption and a more potent stimulus for appetite than for Westerners.

Finally, this study illustrates the value of cross-cultural research to illuminate dietary psychology and behavior, demonstrating that people outside the modern food environment do not show better sensitivity to internal signals during meals, and may in fact show less if they do not habitually self-monitor intake out of concern for overeating. While several aspects of the modern environment undoubtedly promote the unprecedented prevalence of obesity in the West, it is difficult to untangle the dynamic influences of different variables by studying only humans enmeshed in that environment. Animal models are useful for basic physiological and biopsychological questions but are inadequate for studying higher-order cognitive and sociocultural processes that powerfully shape behavior, and it is inappropriate to generalize from animal models to “humans” without understanding the scope of diversity and commonality across present-day human cultures. As research on the motivation to overeat is often framed with overly general speculation about human evolutionary history of adaptation to a feast-or-famine environment, there is much to be gained from understanding the actual ways that humans respond to those challenges.

Author contributions

All authors participated in planning and conducting the experiment. J.D.H. supervised the local research assistants. K.P.M. and J.M.B. analyzed the data. All authors interpreted the results. K.P.M. drafted the manuscript. All authors revised the manuscript and approved the final version.

Declaration of conflicting interests

The authors declare no conflicts of interest with respect to their authorship or the publication of this article.

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